Bioassessment with Benthic Macroinvertebrates

Presented to the Virginia Ad Hoc
TMDL Committee

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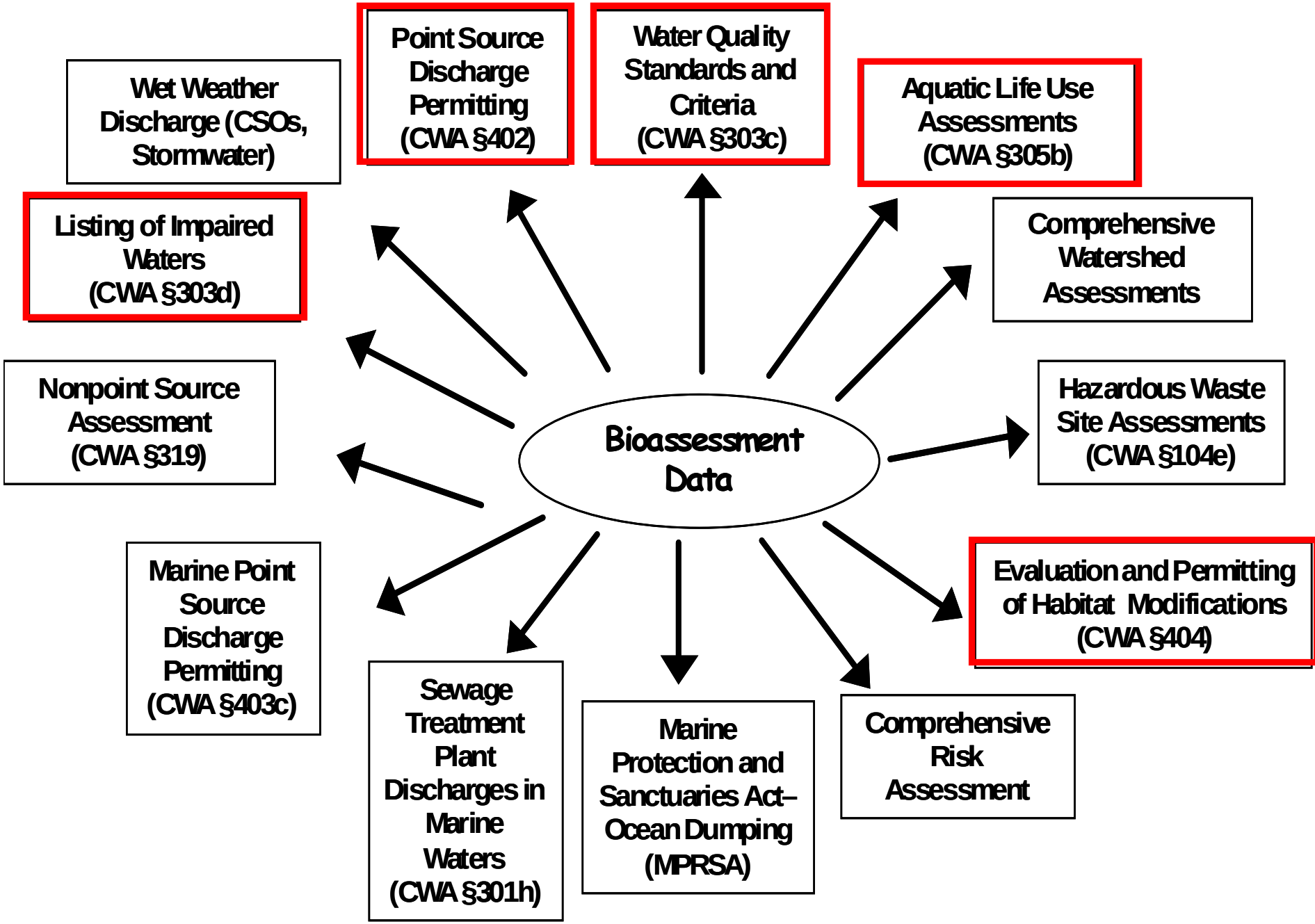
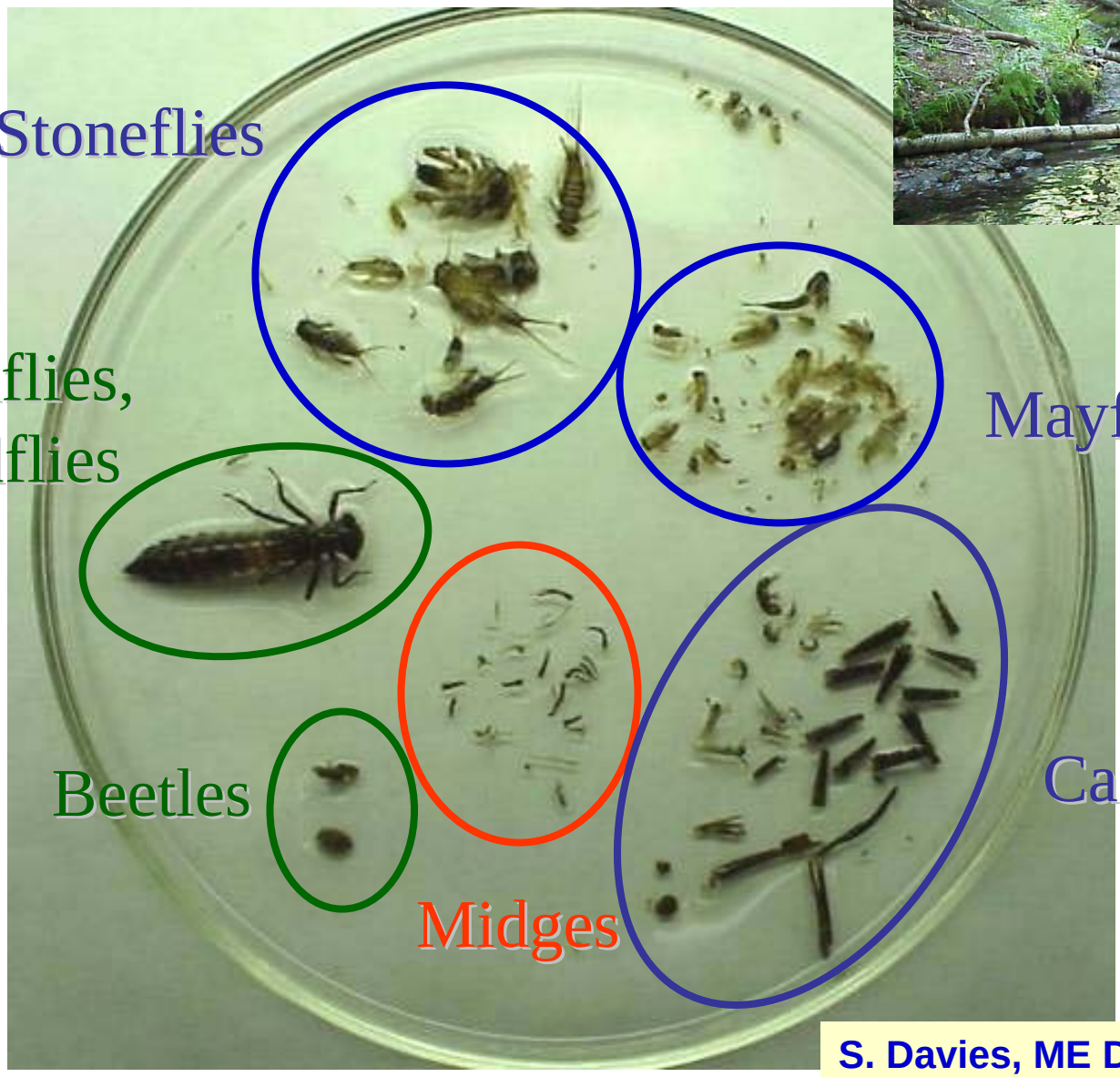
Bioassessment is a legitimate tool to define aquatic life use attainment

- Methods are widely tested and peer reviewed
  - Many studies published in JNABS
  - Considered a “settled” science

- Benthic macroinvertebrates widely accepted as the best indicator of aquatic life (fish or algae also used by some states)

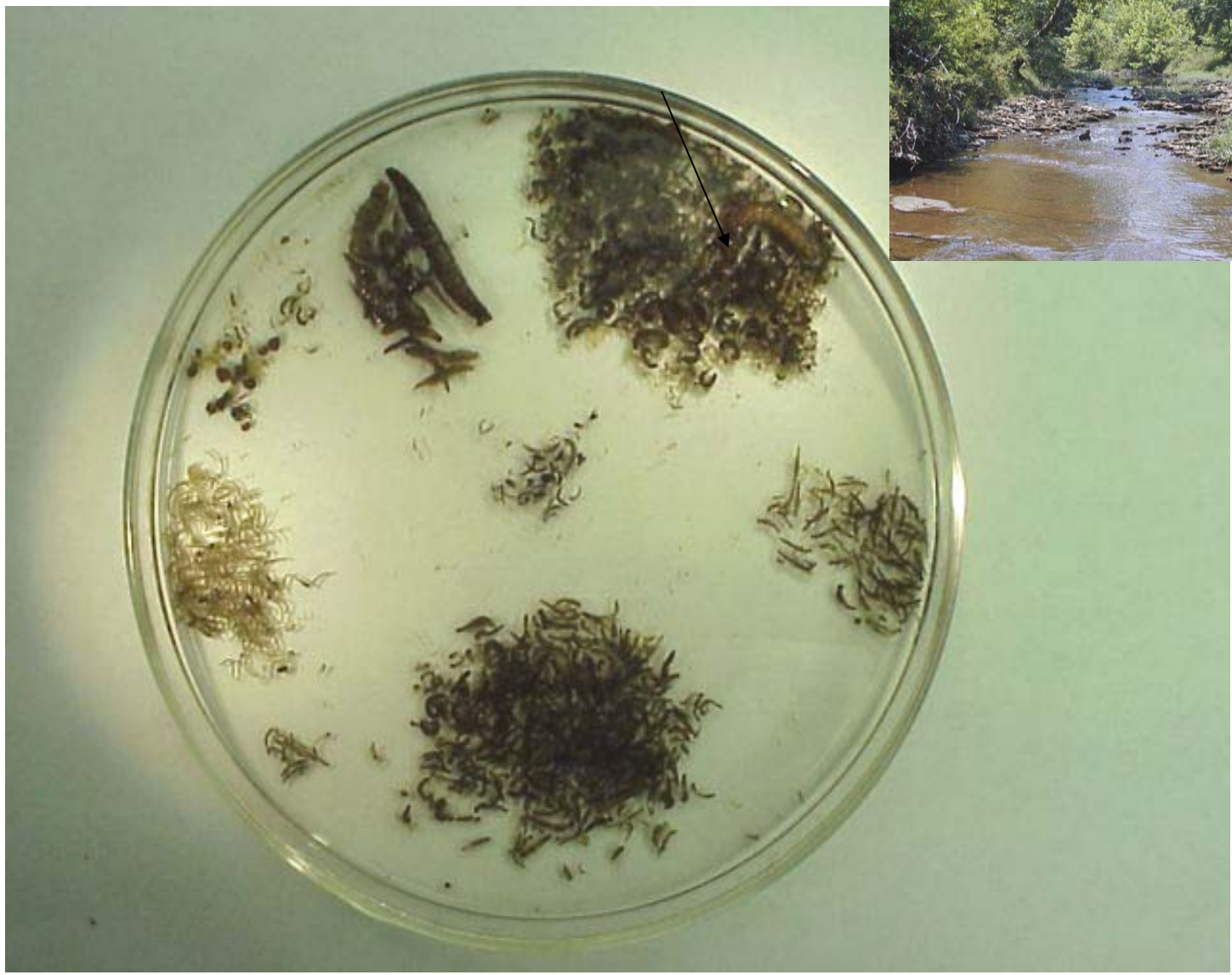

Point Source Discharge Permitting (CWA §402)
Water Quality Standards and Criteria (CWA §303c)
Wet Weather Discharge (CSOs, Stormwater)
Aquatic Life Use Assessments (CWA §305b)
Listing of Impaired Waters (CWA §303d)
Comprehensive Watershed Assessments
Nonpoint Source Assessment (CWA §319)
Bioassessment Data
Hazardous Waste Site Assessments (CWA §104e)
Marine Point Source Discharge Permitting (CWA §403c)
Evaluation and Permitting of Habitat Modifications (CWA §404)
Sewage Treatment Plant Discharges in Marine Waters (CWA §301h)
Marine Protection and Sanctuaries Act– Ocean Dumping (MPRSA)
Comprehensive Risk Assessment

A Reference Community



S. Davies, ME DEP

Moderately Impacted



1 inch

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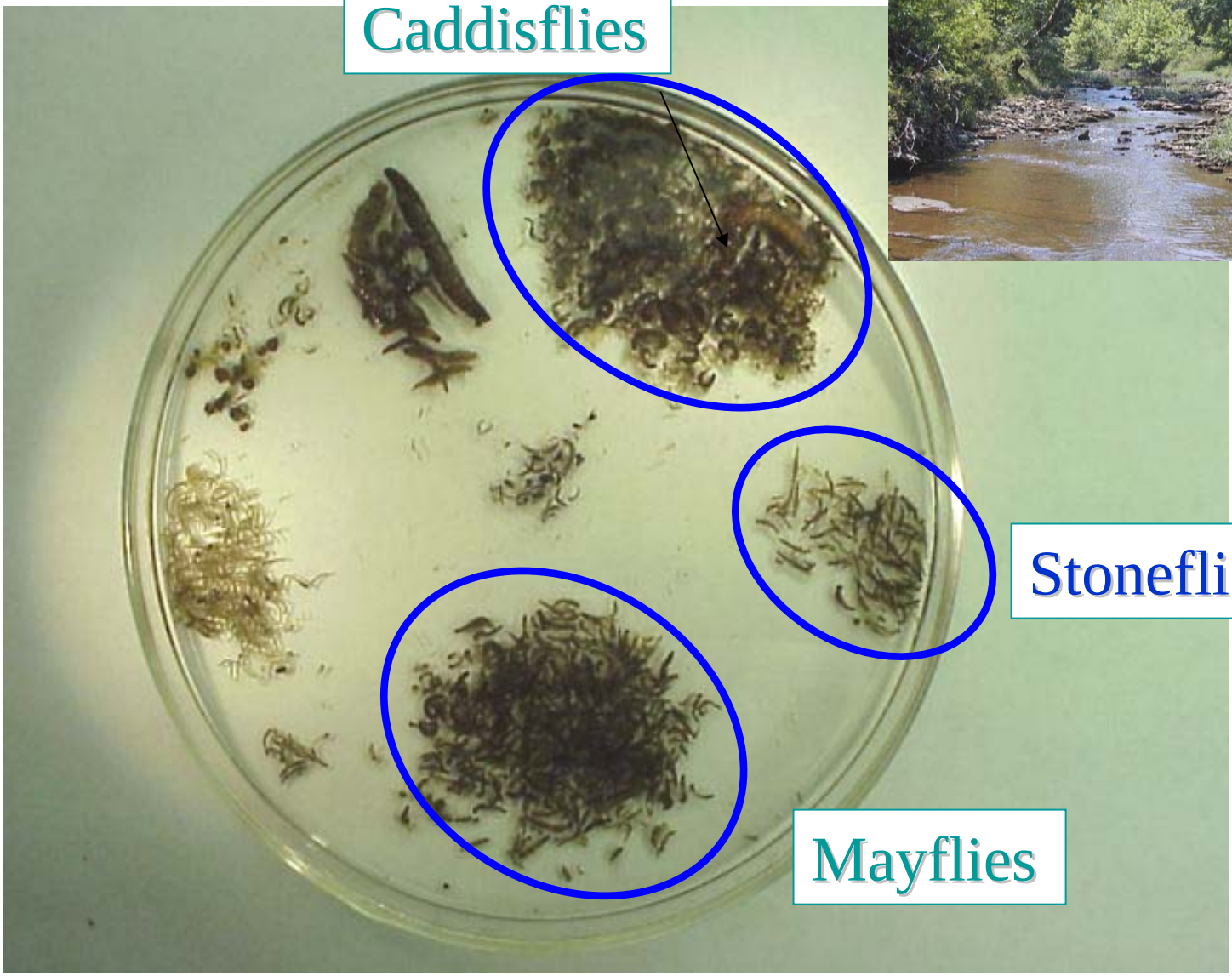

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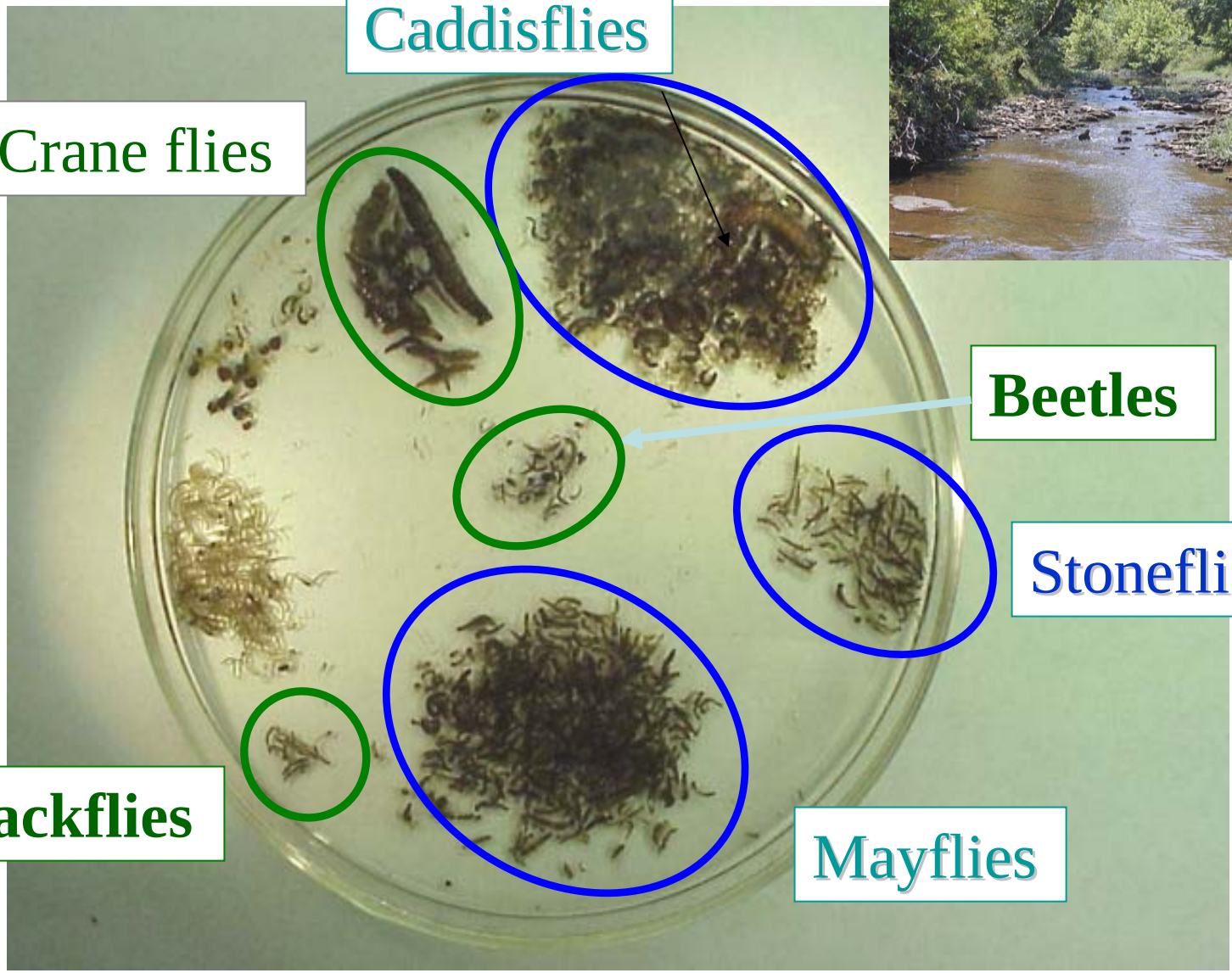

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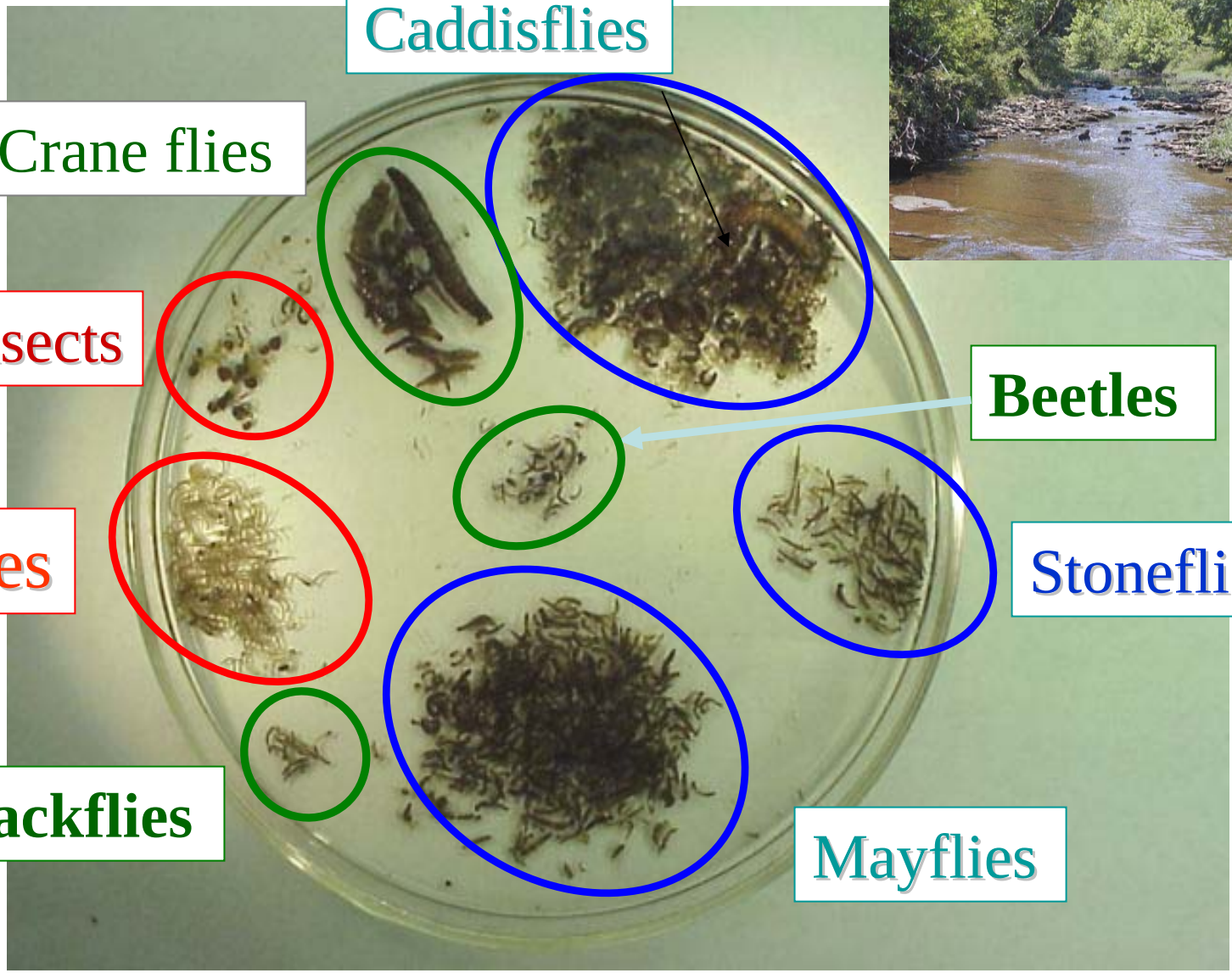

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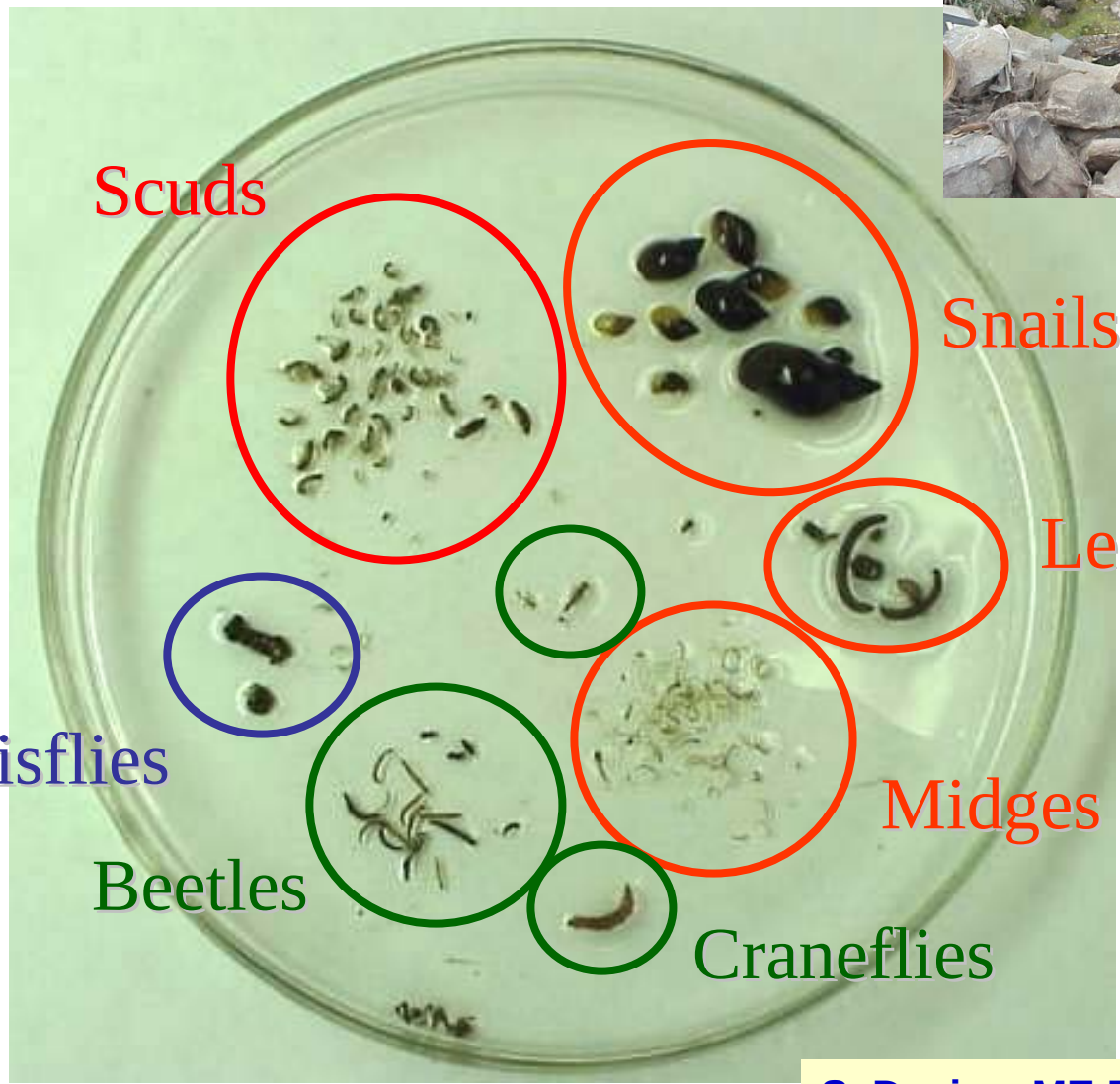
Severely Impacted



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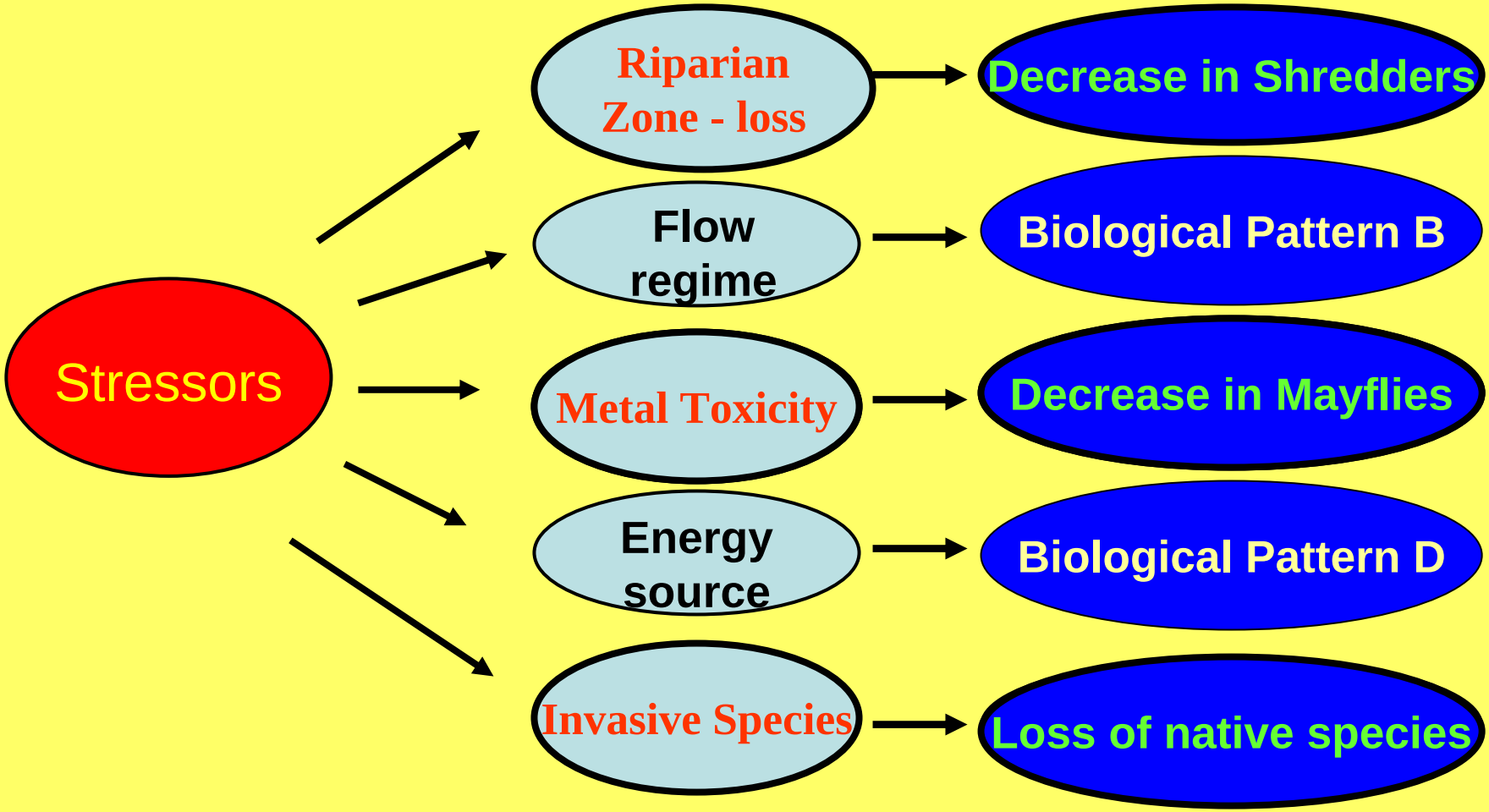
Biological Indicators Can Help Diagnosis



Human activity: "the drivers" → **Altered water resource features** → **Biological endpoint**

Modified from Original Courtesy of Dave Allan, Univ of MIchigan

Constructing a Multi-metric Index

- *Metrics* are numerical summaries of biological attributes
- Span wide scope of community ecology (richness, composition, tolerance, feeding, habit)
- Metrics are chosen that can:
  - Discriminate between known reference sites and degraded sites
  - Respond to stressors
  - Not show strong redundancy with other metrics
  - Demonstrate low variability within the reference distribution

RBP II

- Originally published in 1989 (users have option of slightly modifying)
  - Test sites compared to a single reference site
  - Uses 8 metrics calculated with Family-level data
  - Metrics scored as a %of reference metric value
  - Condition categories assigned as a % of reference total score
- Metrics were never tested for individual states or regions
- But, most metrics now known to work on broad regional scales and even nationally
- Latest RBP (1999) recommends entirely different index development procedures

VA Stream Condition Index (VSCI)

- A Multimetric Index calibrated to a “reference condition”
  - The range of biological, physical and chemical conditions from a population of least-disturbed sites within a region(s)
- Metrics chosen using up-to-date peer-reviewed screening techniques
- Statistically evaluated and calibrated with Virginia DEQ data
- Recently validated with independent data set (draft report in prep.)
- Uses 8 metrics spanning richness, composition, tolerance, and functional attributes
- Scoring is standardized to the entire reference distribution
- “Impairment” threshold set at the 10%ile of reference scores

RBPII vs. VSCI

- Compared the assessment outcomes of 117 stream surveys

	VSCI	
RBP	Non-impaired	Impaired
Non-impaired	56	9
Impaired	13	39
Total	69	48

81% agreement

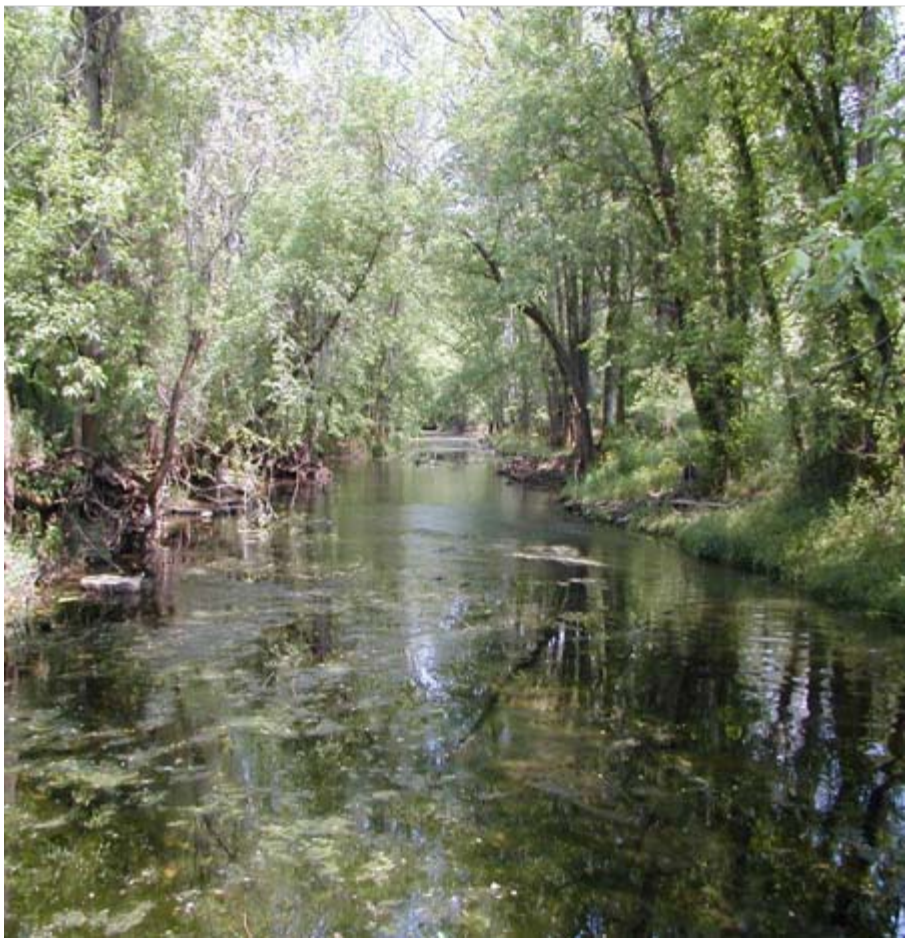
- RBP II performed better (agreed with SCI) when regional reference sites were chosen
- When upstream “control” sites were used, RBP II disagreed with VSCI more frequently

Bioassessment data tracks stressors (examples from the region)

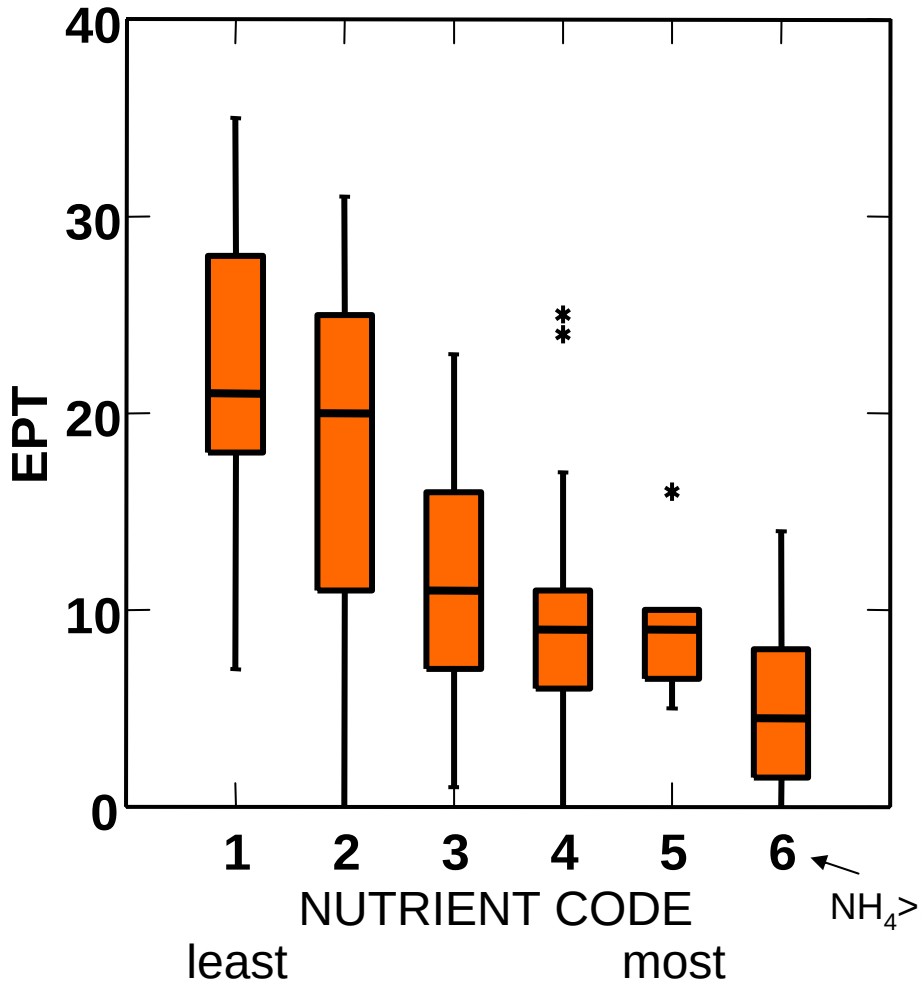
- Nutrients
  - Not a toxin, but elevated amounts causes shifts in community composition, excessive algal growth, D.O. problems
- Conductivity/TDS
  - Increased salinity toxic to freshwater organisms, individual ionic constituents also harmful
- Habitat Degradation
  - Non-toxic (except excessive sediment). Quality dictates what species can maintain populations

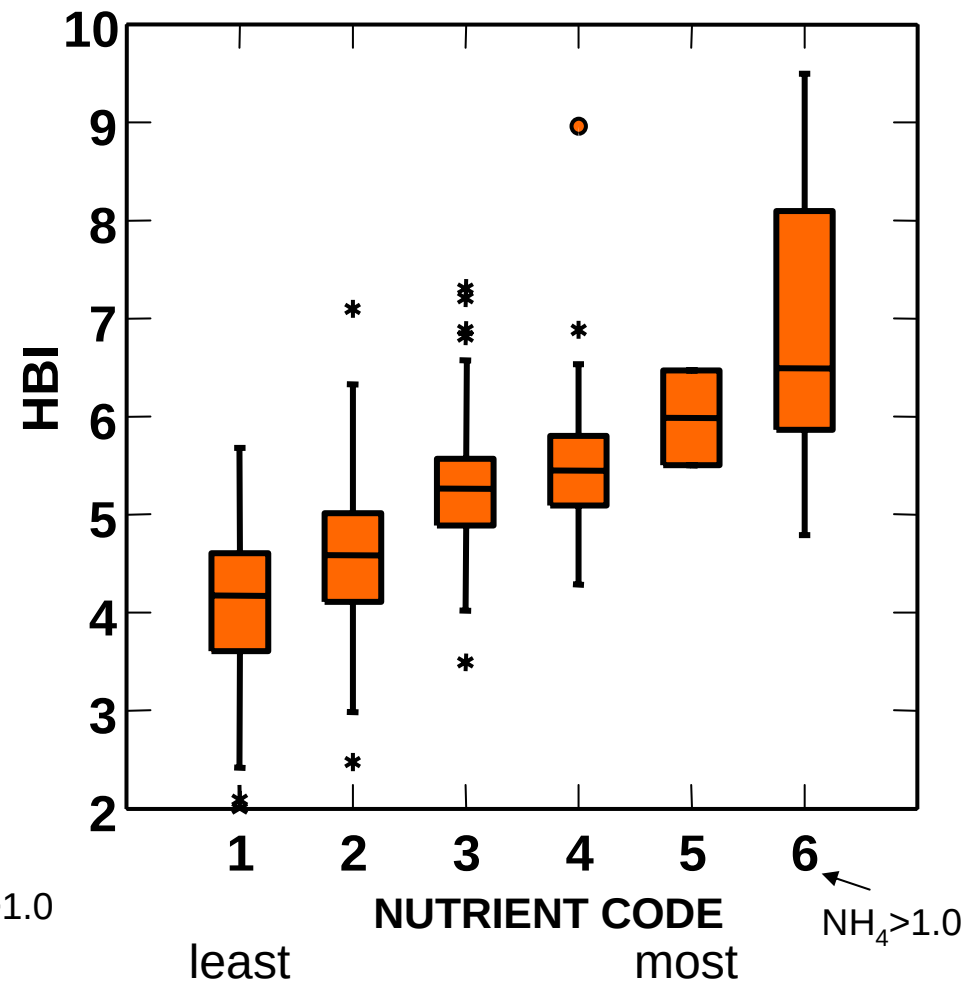
Response to Stressors

Nutrient Enrichment



Nutrient Enrichment
Kentucky

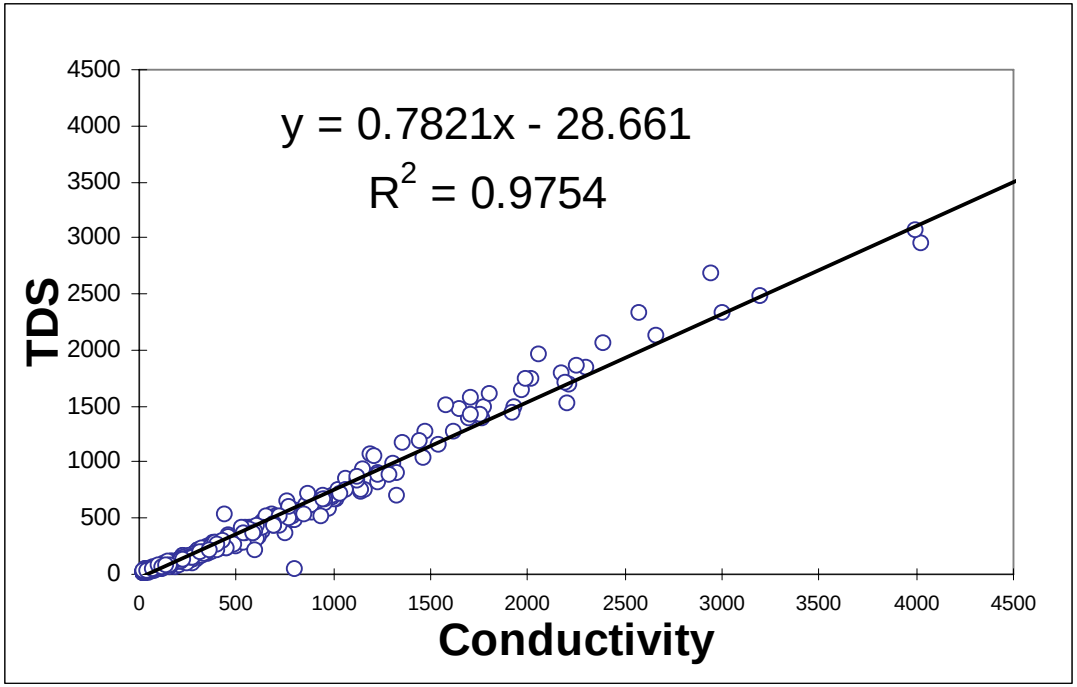




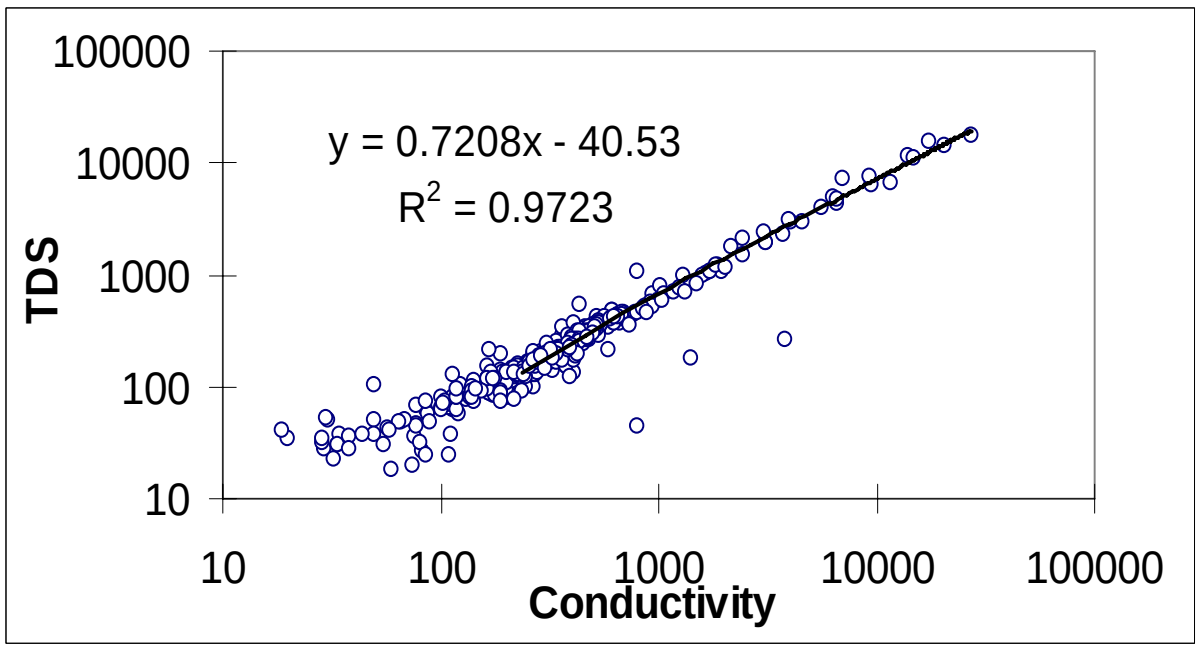
Conductivity/TDS

(non-acidic, pH 6.0—8.5)

Conductivity



KY Appalachian Headwaters (sandstone)

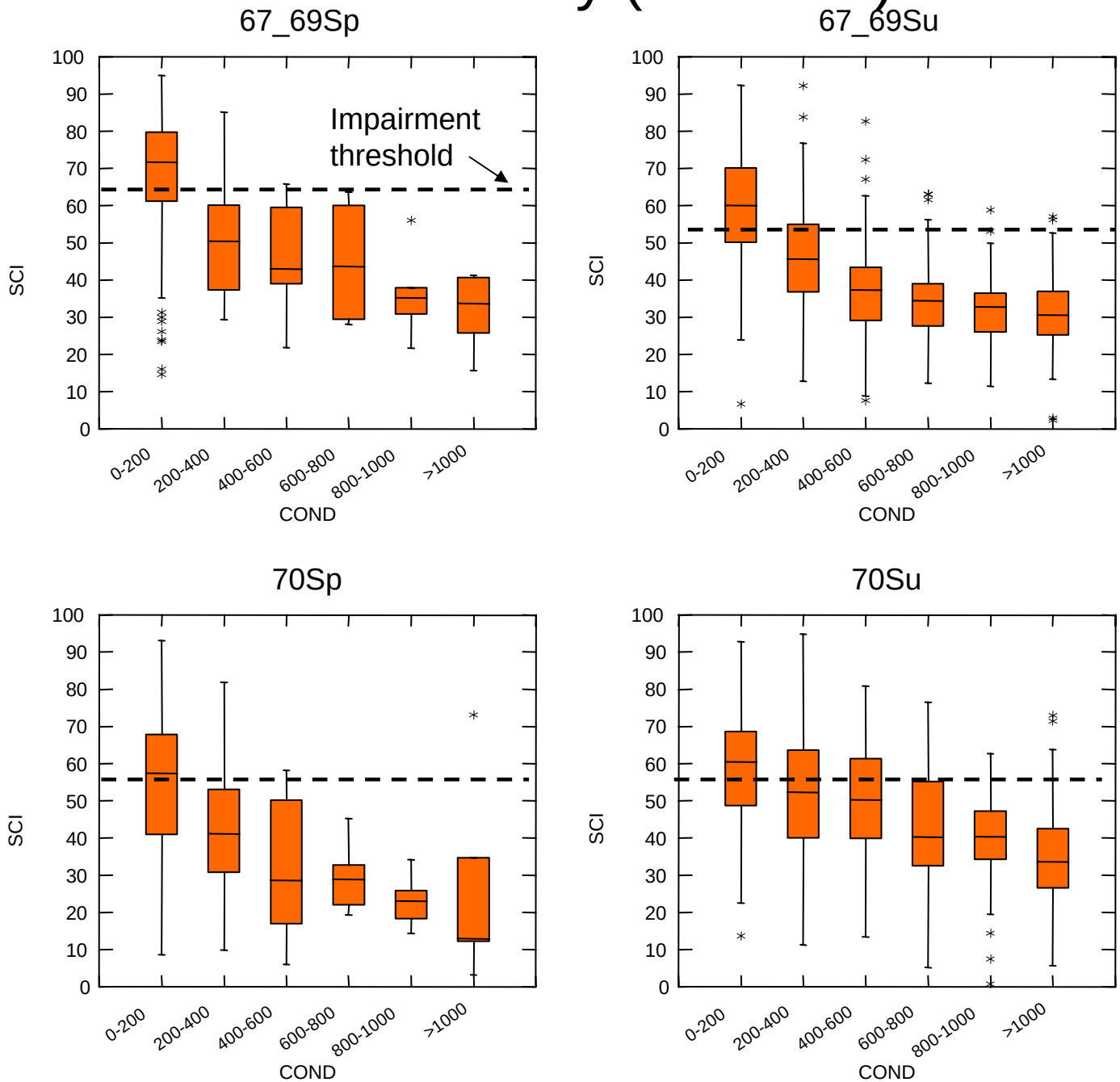


KY Statewide (Incl. limestone areas)

Conductivity/TDS

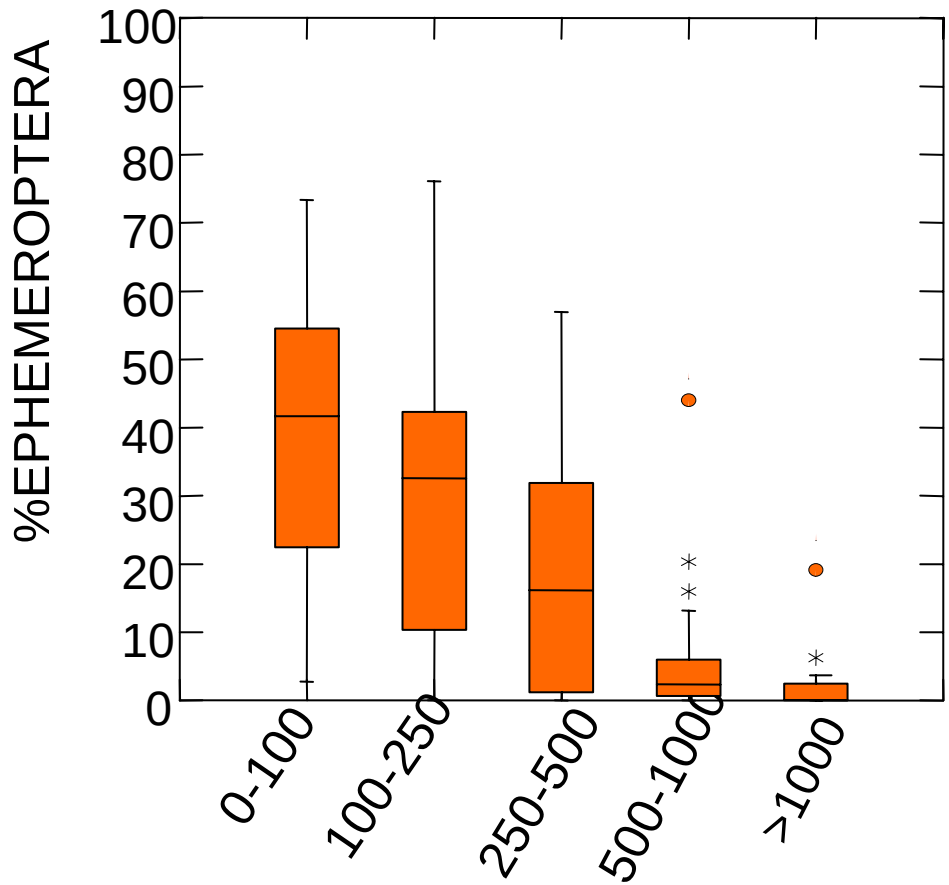
- Most streams in the region are naturally dilute
- Stream invertebrates physiologically adapted to low TDS
- Empirical datasets show TDS is a stressor of concern
- Toxicological literature states that elevated TDS is toxic
- However, tox studies traditionally use cultured organisms that coincidently are highly tolerant to TDS
- Generally, TDS thresholds derived from lab tests are inadequate to protect aquatic life in region's streams
  - For example:
    - a NOEC for *Ceriodaphnia* = 1200 μS/cm
    - A LOEC for *Ceriodaphnia* = 2050 μS/cm

Conductivity (WV data)



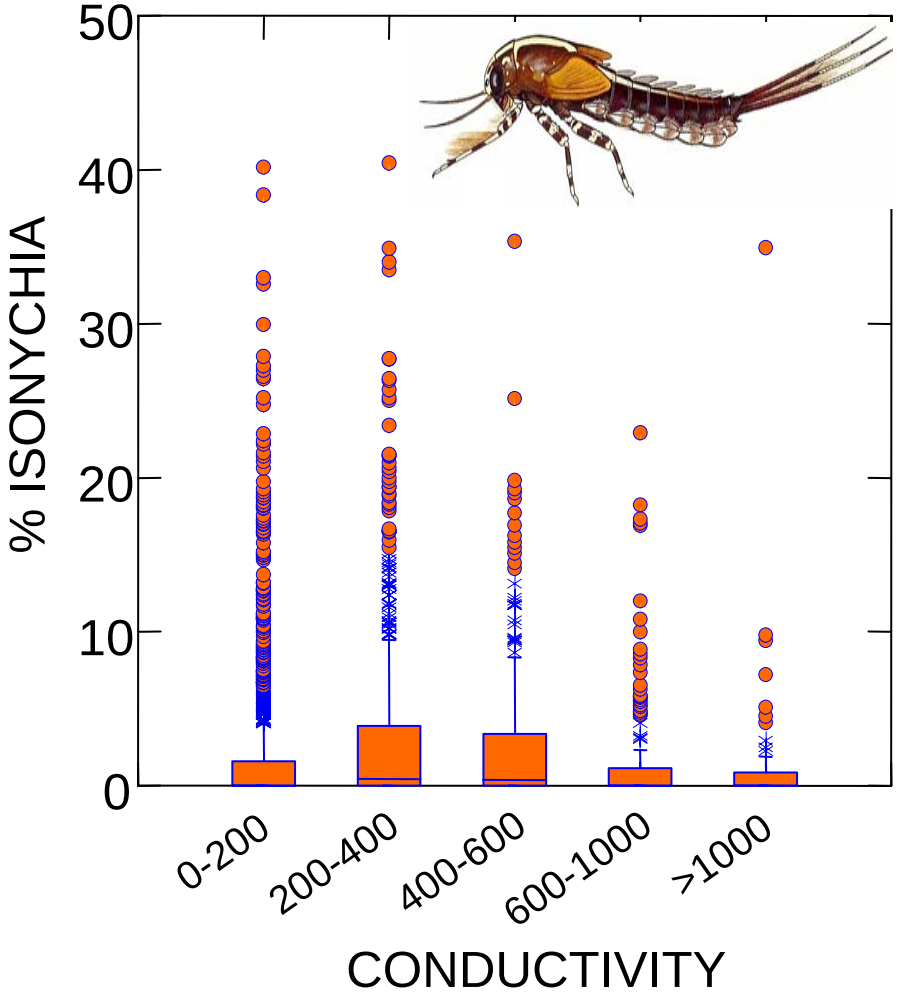
Mayflies and Conductivity

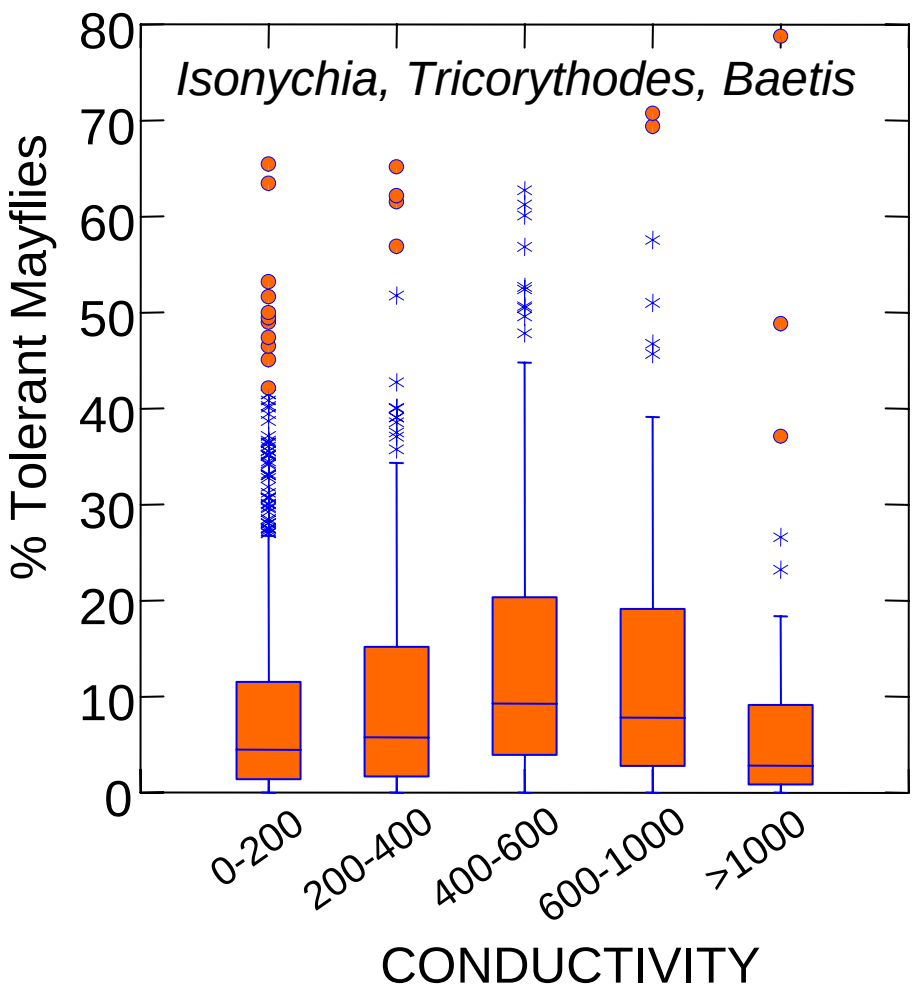
- Ephemeroptera often accounts for 30-60% of benthic sample in healthy streams
- declines with increasing conductivity/TDS



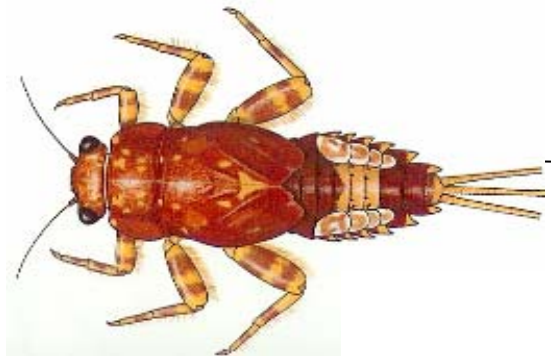
KY Appalachian Headwaters

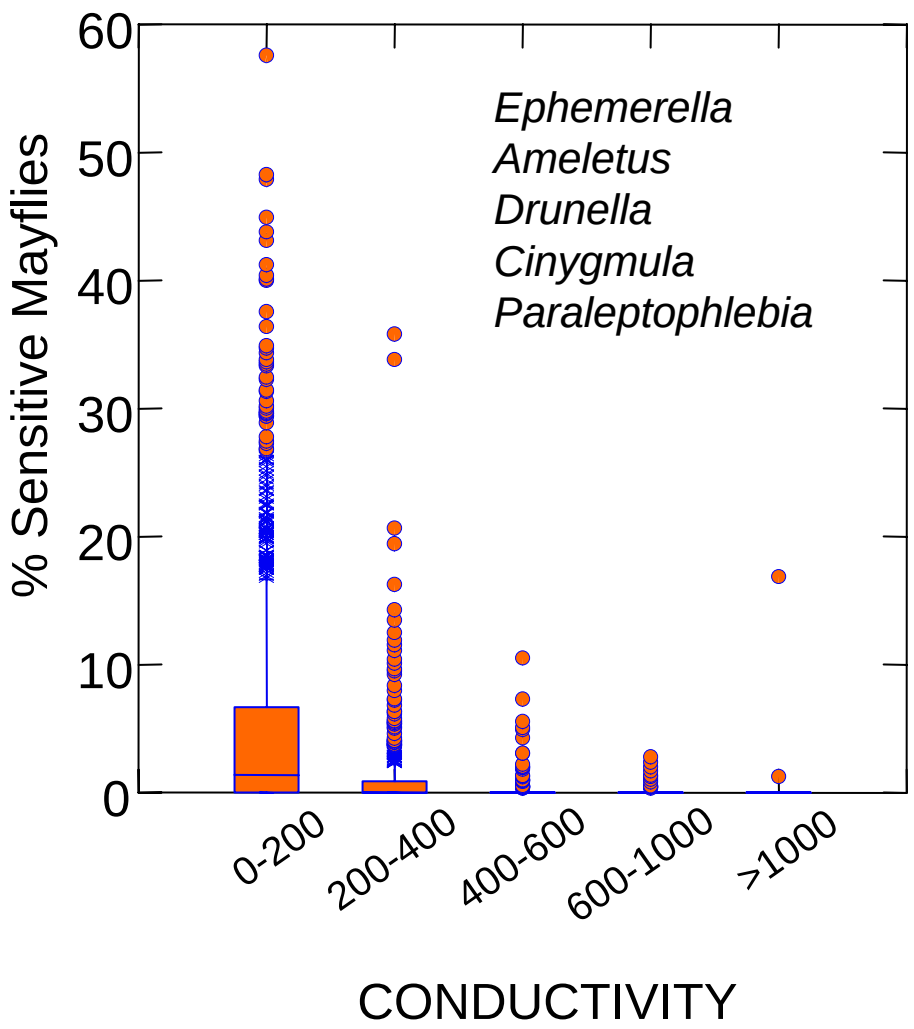
Mayflies and Conductivity (WV data)
Tolerant Types





Mayflies and Conductivity (WV data)
Sensitive Types



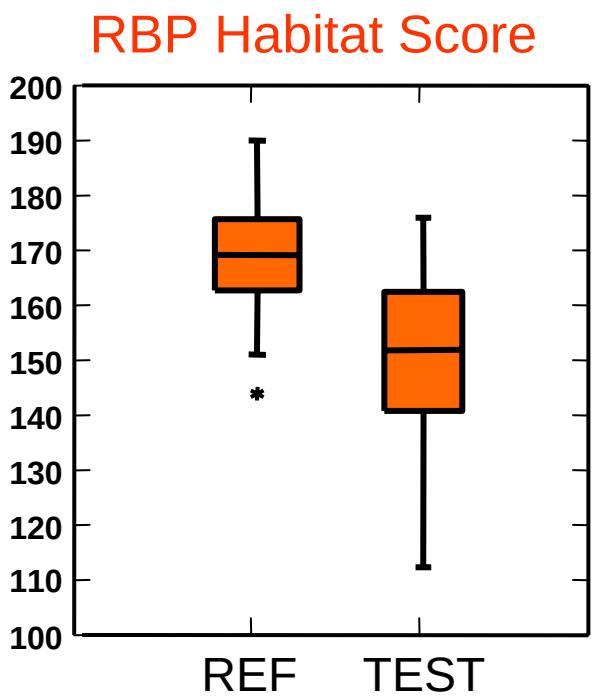


Habitat Alteration

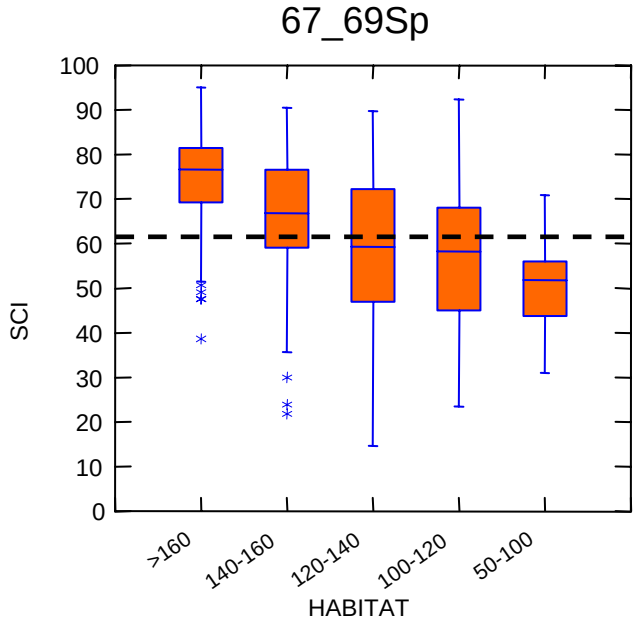
RBP Habitat Scores

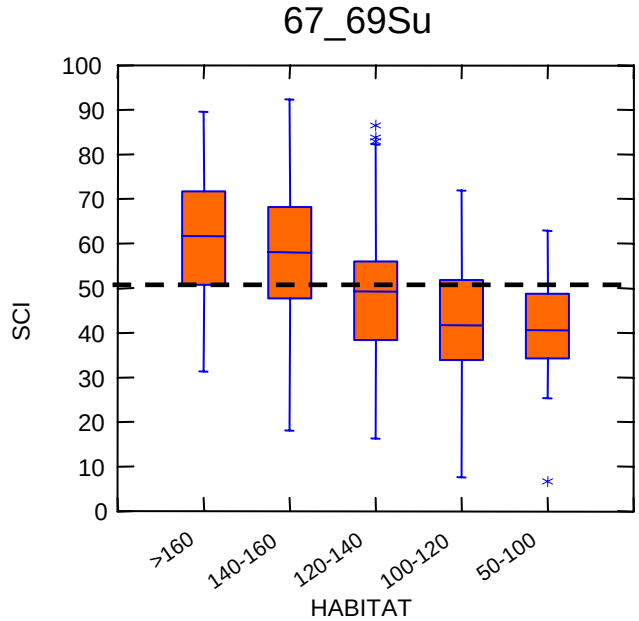
- 10 metric, qualitative habitat rating (scored 0-200)

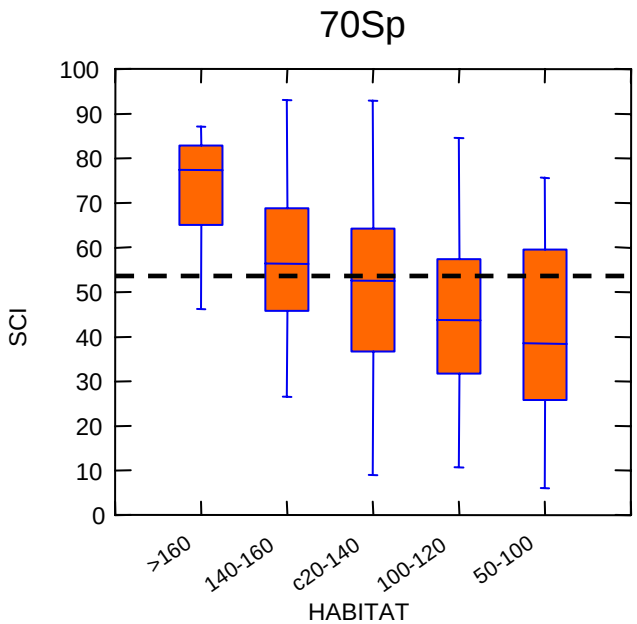
Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstab or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 (
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boul particles are more than 75 surrounded by fine sedim
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 (
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Sow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slo deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 (
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradie of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 (
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in chann and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 (

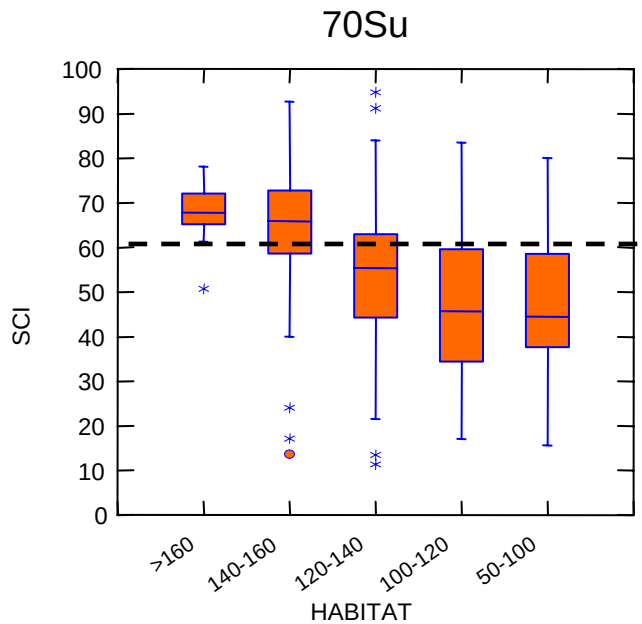


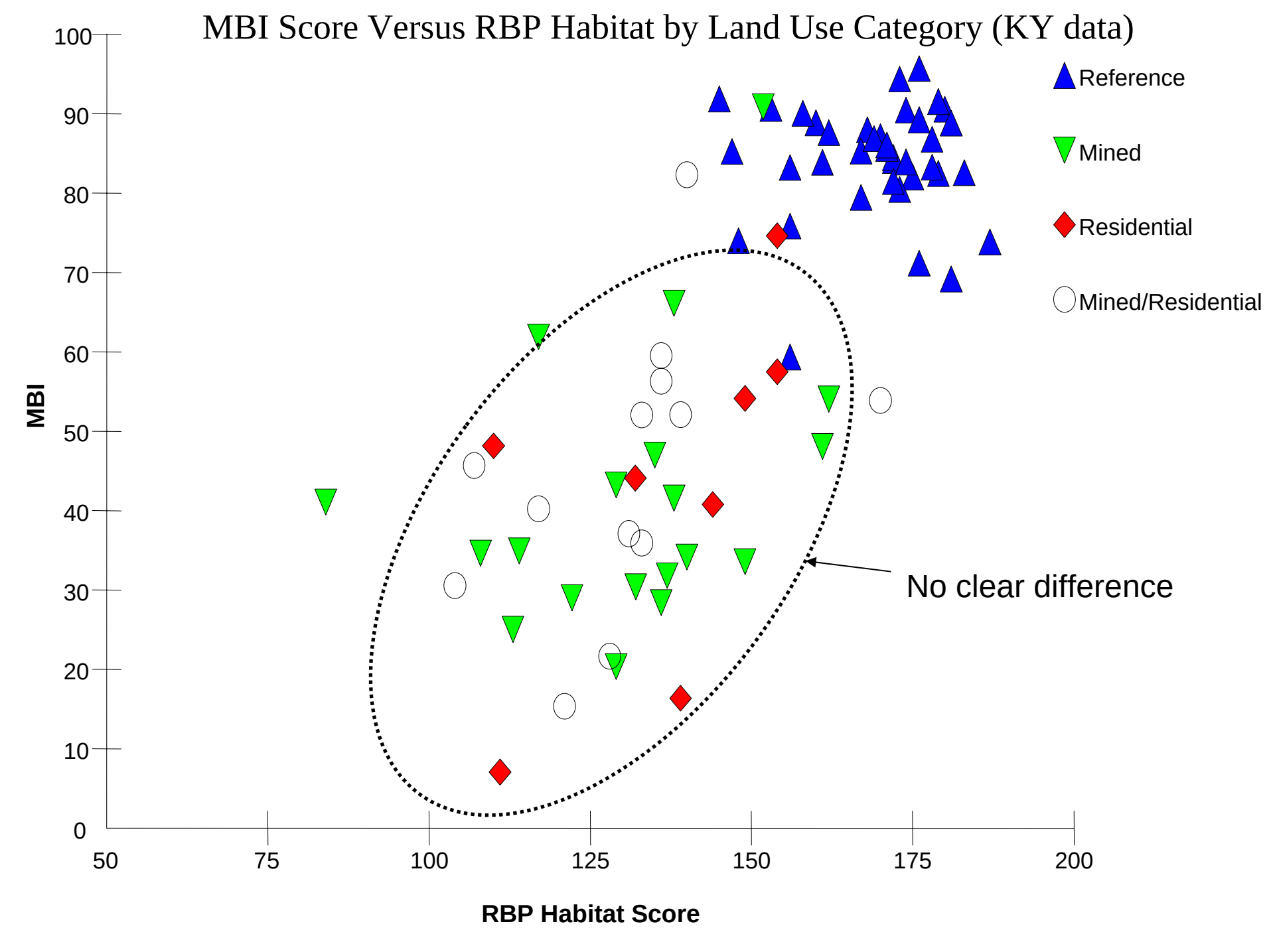
RBP Habitat Scores vs. SCI (WV data)



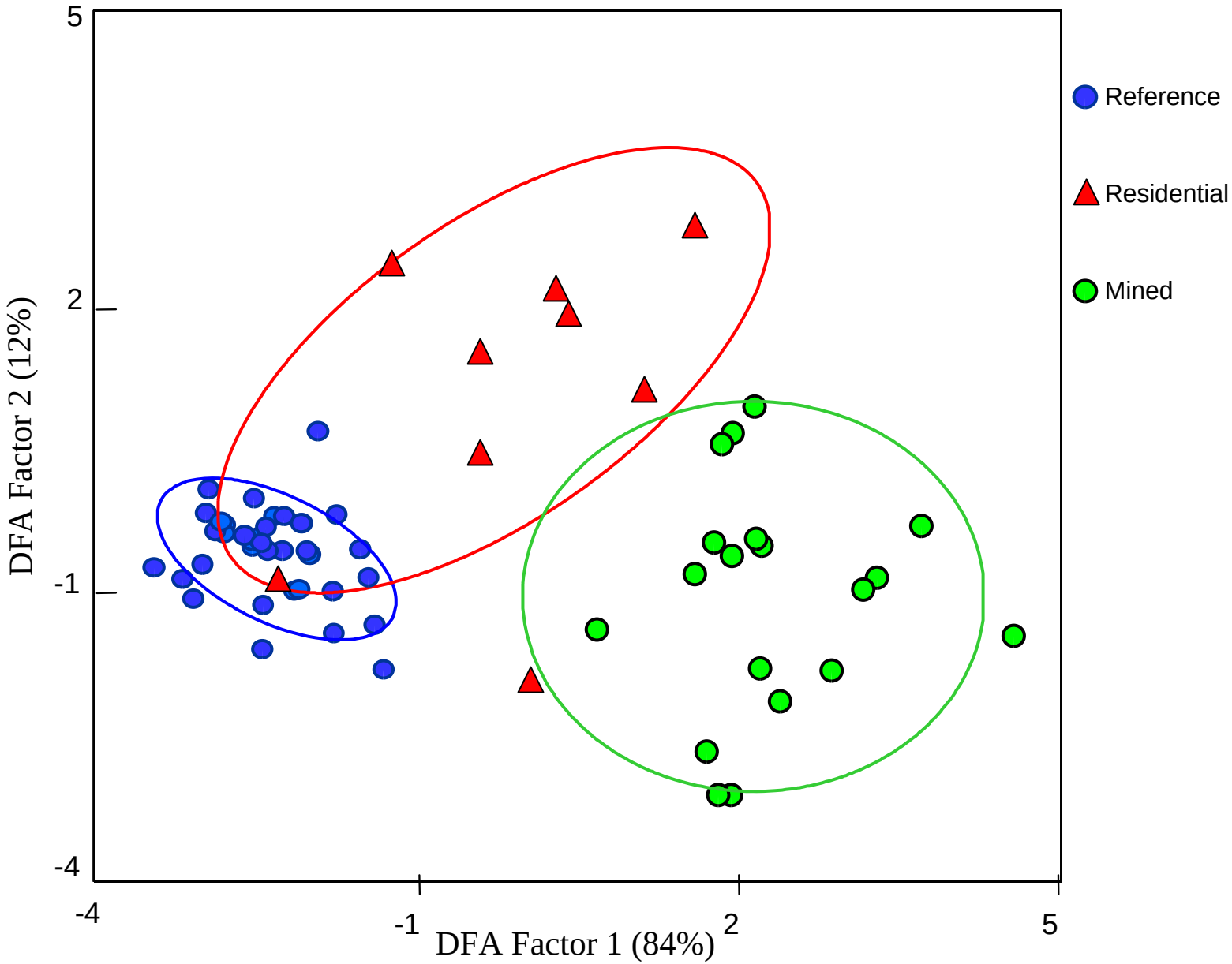




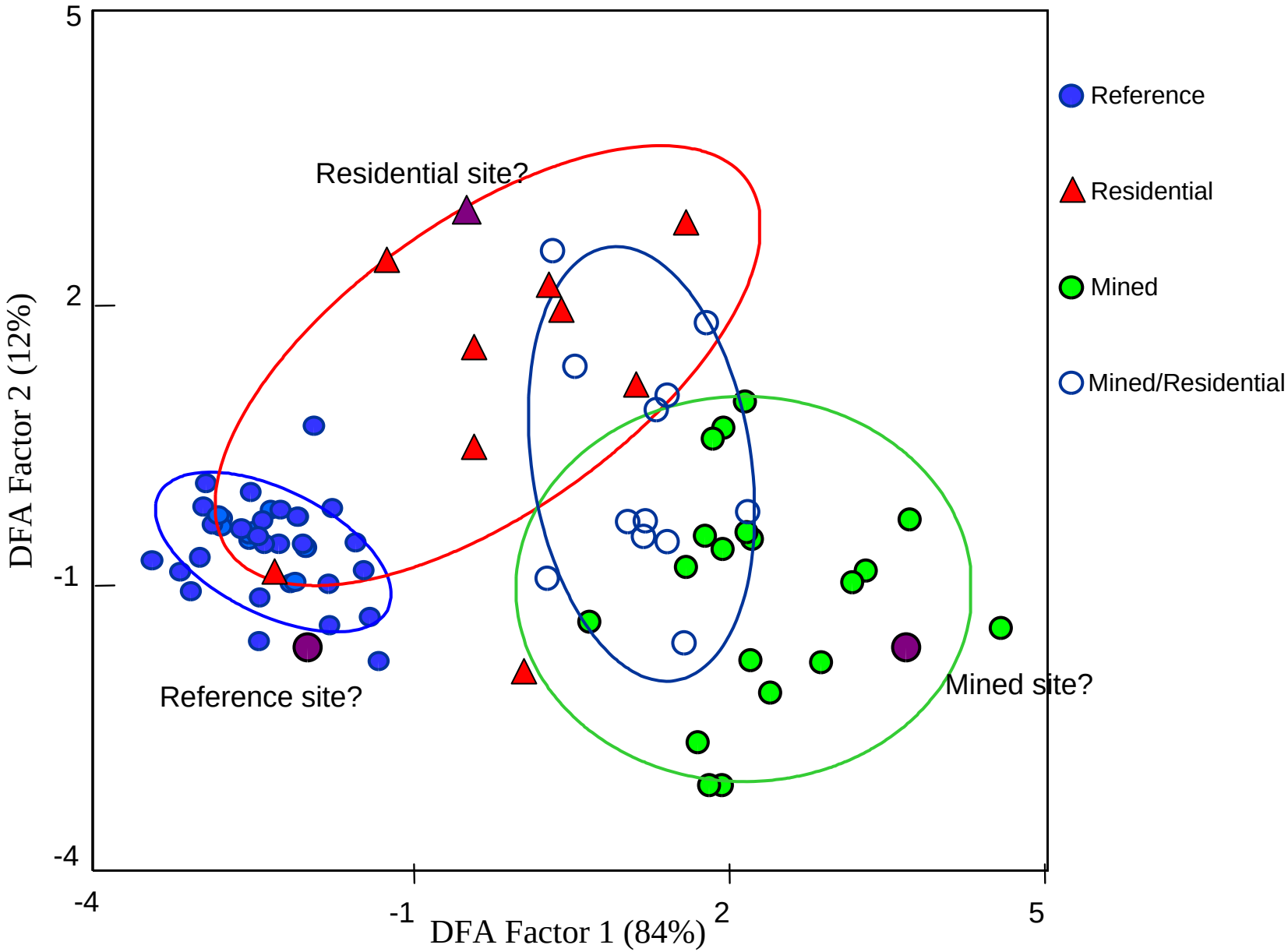



MBI Score Versus RBP Habitat by Land Use Category (KY data)
MBI
RBP Habitat Score
100
90
80
70
60
50
40
30
20
10
0
50
75
100
125
150
175
200
Reference
Mined
Residential
Mined/Residential
No clear difference

Stepwise Discriminant Function Analysis Plot using %mEPT, %Ephem, mHBI, Total RBP Habitat Score, and Conductivity



Stepwise Discriminant Function Analysis Plot using %mEPT, %Ephem, mHBI, Total RBP Habitat Score, and Conductivity



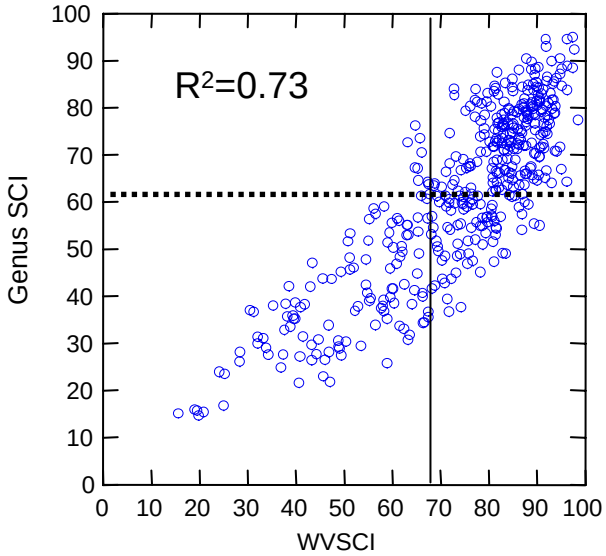
Conclusion

- Bioassessment is the most direct means to determine the Aquatic Life Use of a waterbody
- Benthic macroinvertebrates are the most widely used indicator of ALU impairment or attainment
- These organisms are the most reliable indicators of human stress
- Biological data can help with diagnosing causes and sources of impairment
- Benthic TMDLs (or 303(d) listings with benthic data) are nationally widespread and a reality


Questions?

Genus vs. Family SCI Scores (WV Data)

67_69Sp



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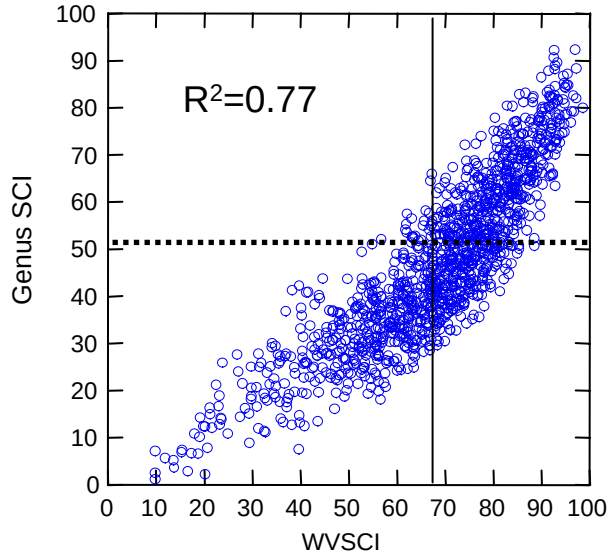
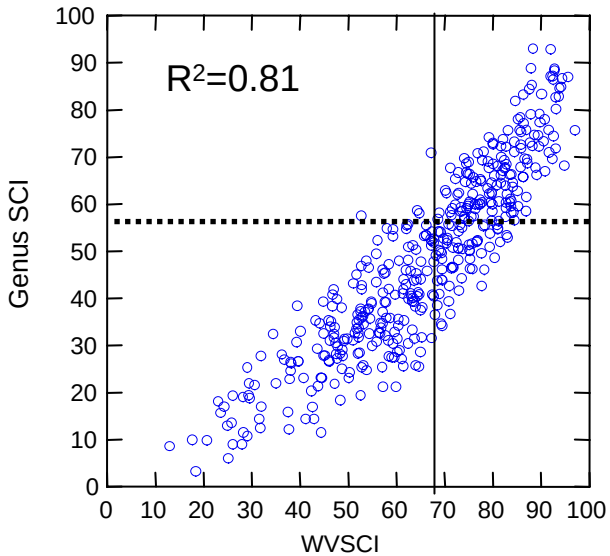
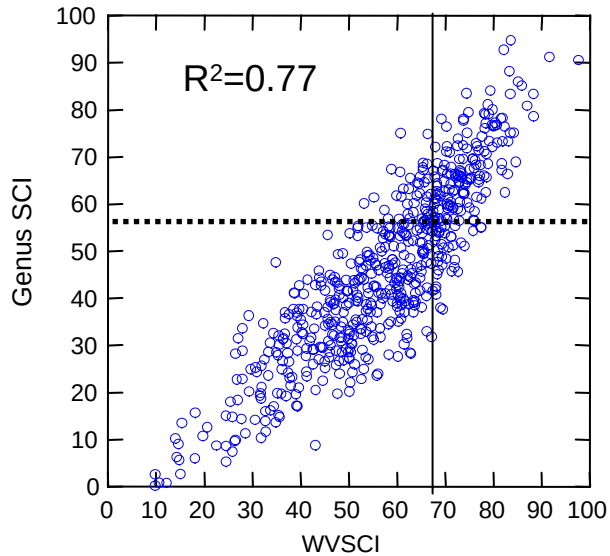


70Sp



70Su



VSCI Precision Estimates based on 16 replicated samples

StationID	VSCI_REP1	VSCI_REP2
4AEKH003.18	52.14	45.63
4ARNF009.01	60.98	65.8
9-LIC004.73	71.56	76.6
9-WLK024.17	62.64	66.72
1AGAN000.32	67.64	64.75
2-CAT026.55	36.45	32.45
2-HAK004.34	51.28	62.19
4ABOR033.22	74.84	75.14
4AMCG000.56	39.44	56.39
6ADIS013.73	69.74	65.92
9-DDD006.61	76.87	80.37
9-WLK026.82	64.91	60.57
2-RKF026.13	69.03	60.64
2-WDC002.90	70.89	76.56
4ABWR029.51	60.66	55.37
5ANTW093.62	73.4	69.7

SD=4.77

90% CI = 7.8 (two-sided),
6.1 (one-sided)

%CV= 7.5

Precision Estimates based on 81 replicated samples (WV data)

Stream_Name	Dup #1	Dup #2
Abram Creek	50.2	50.9
Beech Creek	31.1	28.9
Big Coal River	39.8	39.1
Big Creek	38.8	34.1
Big Horse Creek	33.8	33.0
Big Run	81.3	94.5
Bingamon Creek	37.0	47.0
Blue Creek	51.6	47.9
Bluelick Branch	49.5	54.9
Bryan Creek	52.2	54.7
Buffalo Creek	67.1	61.6
Charity Fork	25.8	32.4
Cross Creek	53.7	50.9
Days Run	17.0	28.1
Duck Creek	48.0	53.4
Fields Creek	35.1	32.7
Fish Creek	65.4	62.6
Flatfoot Creek	78.5	72.2
Foxtree Run	47.3	55.8
Glady Fork	66.5	71.0
Goose Creek	37.5	38.5

SD=5.74

90% CI = 9.3 (two-sided),
7.3 (one-sided)

%CV= 11.5